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EMPLOYMENT OF LASCAD PROGRAM TO STUDY THE THERMAL DISTRIBUTION ACROSS ND: YAG DISC PUMPED BY DIODE LASER

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Abstract

The most important characteristic of solid-state laser systems is the homogeneous distribution of the pumping beam within the active medium, which is also closely related to the design of the resonator. In addition, the efficiency of the cooling system, this is responsible for the exchange of heat between the active medium and the external environment..In this project, we hire LASCAD software to design and study the effect of thermal distribution across the disc laser when pumped by a laser diode. This parameter is more important when we want to design and contract of laser system because an inhomogeneous of that causes selffocusing and damage in active media.. We plotted and study this effect on laser system performance.

Keywords: LASCAD; Solid-State Laser Systems; Active Media.

Introduction

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LASCAD is an acronym for **(Laser Cavity Analysis and Design) that** provides us with a pre – geometric understanding of the characteristics of laser systems. Together with (FEA) finite element analysis ,it is to support program that focuses on the issue of thermal distribution in laser systems[1]

Recently, a lot of scientific research has been devoted to the subject of thermal distribution in laser media, especially those that are light pumped, because they do not have self-generating thermal lenses within the active medium, which is the result of temperature increases in certain areas of the medium that are larger than in the vicinity, causing light dimming and thus damage. This phenomenon depends on various parameters, such as the design of the resonator, the distribution of the light pumping beam, and the efficiency of the cooling system Used. All of this called for the use of computer simulations to develop appropriate optical designs before the construction of laser systems of this type could begin[2].

Theory

Small Signal Gain and thermal limits factors

One of the most important things that to controls the dimensions of the laser medium is the thermal fraction limit. The maximum thermal power that the medium sustains when that cooling on one face, of it, can is given by [3].

$$P_T = 6\,\gamma\,R_s\,\left(\frac{S}{t}\right) \quad \text{.....(1)}$$

Where Rs is crystal thermal effect factor for Nd:YAG (10W/cm^2), S is the area of an effective medium face ,(t) is the active medium thickness ,(γ)is a constant that has to do with the safe operation of a laser ;when its 4.5 that means that a laser system works at one-quarter of full value of power. The maximum power that can be absorbed by the laser medium is given in the following [3,4].

$$P_a = \frac{P_t}{\eta_n} \quad \text{.....(2)}$$

Where η_n is heat capacity of any exited state (0.32). The small signal gain coefficient of 1.7cm^{-1} can be calculated from following relationship

$$g_o = {}^{P_a}/_{VI_s} \quad \text{.....(3)}$$

Where V is the active medium volume, I_S is the saturation of intensity for Nd: YAG and given by

$$I_s = \frac{h\nu}{\delta\,\tau_f} \quad \text{.....(4)}$$

δ: Emission cross section, T_f : lifetime of high level, (h) Blank constant And with Lambert Law

$$I = e^{-\epsilon\,c\,l} \quad \text{.....(5)}$$

Where I: is pumping intensity in disc laser, I_O: is source pumping Intensity , ε:extraction coefficient, c : concentration of the laser medium , l : cavity length .

LASCAD as a Simulation Software

Finite element analysis codes have comprehensive computer programs considered the most common search for the thermal behavior in laser systems. However ,it has been verified by the practical measurements and thermal map. This comparison between computer simulation and experimental results that for diode pumped Nd:YAG solid state laser [5,6]

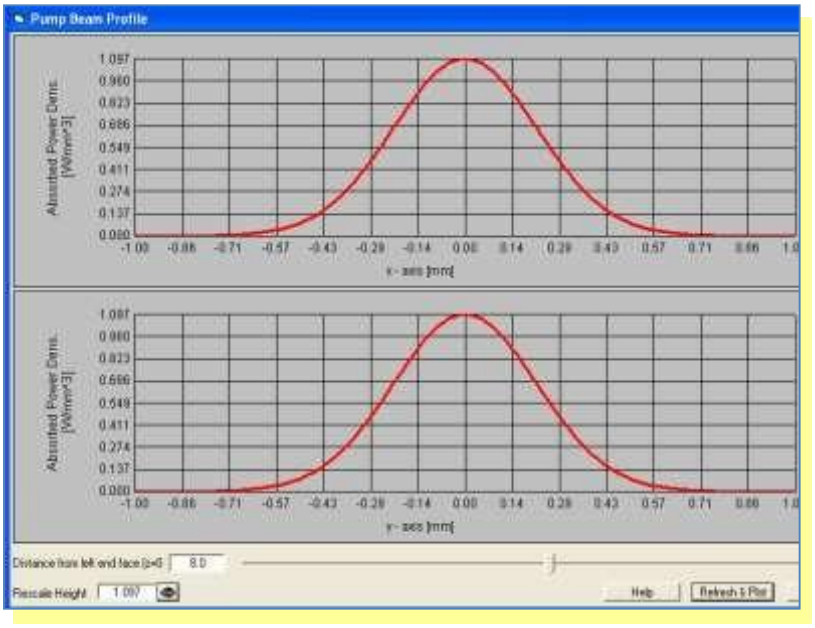
Fig(1) shows the Nd:YAG active medium in LASCAD interface

Finite Element Analysis

When we want to do an analytical study of the relationship of heat to the structure of matter, we must have solved the differential equations for the ultra –fine element analysis model was used with semi –deformation grids because it has useful capabilities for simulating laser operation and applications.[7,8],

- Quasi – irregular can map the temperature distribution within the crystal structure ,it's an excellent analysis and it has successive analytical data for the laser system. This mesh can be connected to the surface of the crystal by irregular elements.
- This function allows to use fast computational encryptions that my differ from the time of irregular computer grids that increase as the number mesh points increases.
- Quasi- irregular grids can be extended in three dimensions
- High accuracy can be achieved When we used small grid.

For high accuracy mesh of high dimensions range must be used ,as super Gaussian functions combined with absorption coefficient were used. Figure (2) shows the advance Gaussian curve in combination with an absorption coefficient.

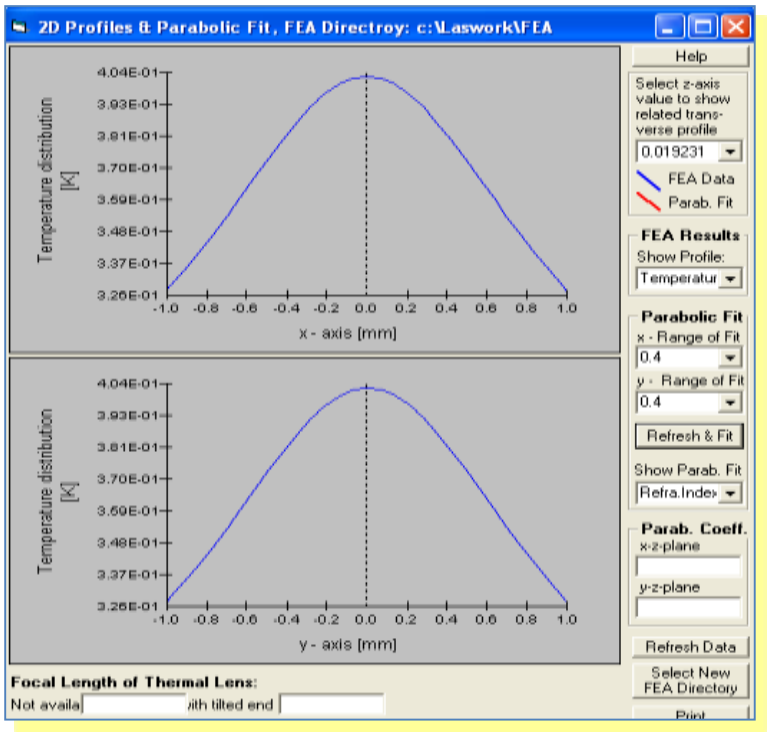


Fig(2) illustrate Gaussian function in combination with an absorption coefficient

Experimental and theoretical study

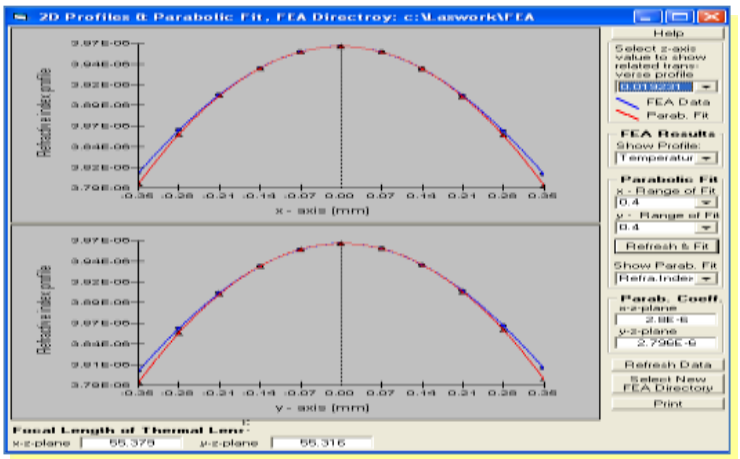
Two – dimensional models can be expressed at different locations for the third

dimension.In our research, the active medium has pumped by the end –pumping method with the diode laser at 810nm,we were placed the amount of fluid cooling system in parallel surface. The thickness of Nd:YAG crystal has 1.6 cm, and 0.2 cm width of square cross section . When we have focused the pump beam next the rod face at 0.1 cm of the entrance face. The beam spot size of the pumping beam was 300 μm with divergence about 42 mrad.the power of the diode laser has 20W. The mesh subdivision created by the FEA correspond the available positions are illustrated in figure (3).



Fig(3) Theoretical temperature shapes

Thermal efficiency was used to compare the theoretical and practical curves, which express the amount of heat that can be converted from pumping energy. Significant correspondence can be observed between the thermal factor of 0.32 and that of the most common[9].from these variables we can conclude that there has a significant agreement between theoretical and practical results. The reason for the asymmetry of the practical curves has the asymmetry of the pumping laser spot. Fig (4) illustrated the profile of experimental and theoretical.



Fig(4) The experimental and theoretical temperature curves

Heat Transfer Measurements With Nd:YAG Crystal

Measuring the thermal transfer coefficient is relatively difficult, but this can be simplified using the thermal mapping method, which provides a simple manner. The thickness of the crystal which has used as an active medium 1.6 cm ,and its cross section 0.2*0.2 cm^2 square ,was paralleled a container that contained a cooling fluid , has used as a cooling system. Figure (5) illustrates the distribution of the temperature when the rod has mounted from by its four faces. In the second case, the temperature gap between the edge of the laser rod and the holder can be clearly observed the thermal map has a parabola at the area under the pumping effect. we also see an exponential decay at the edge of the rod. These results show a great match especially when optical fiber has been used in pumping with a laser diode[10,11].

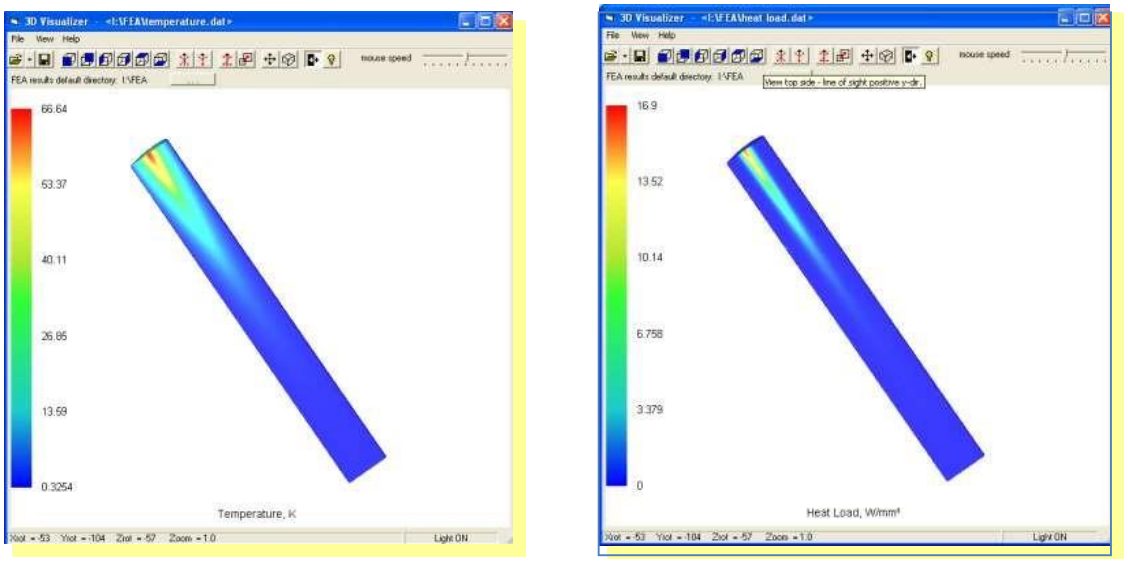
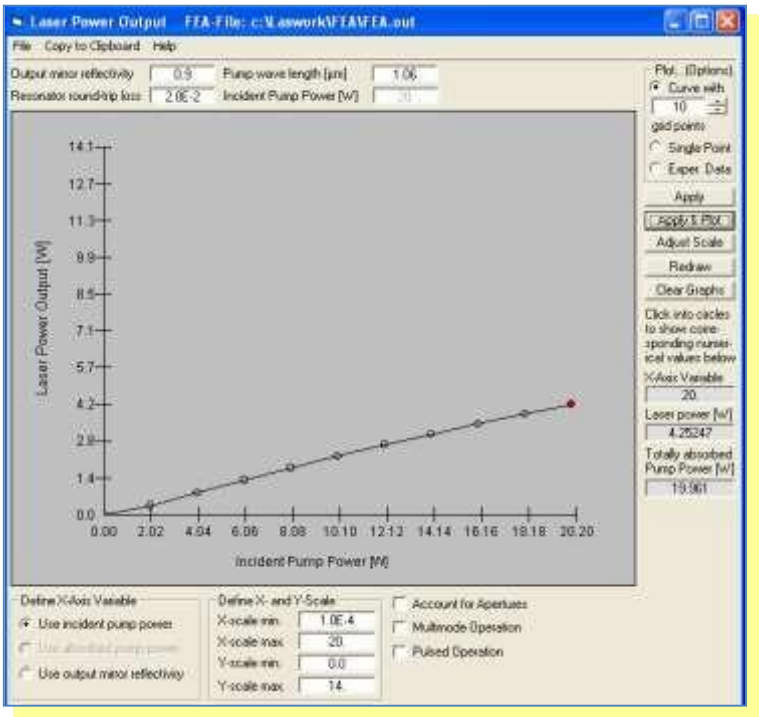


Fig (5) thermal mapping (a) heat load (b) temperature

Study the laser output power of system

In this step we construct the system the system of diode laser pump several discs (10 discs) in series and increasing the spot diameter to 16 mm with constant power.

These discs have arranged in along folded unstable resonators that have very difficult to aligning[12,13]. we obtained 4.25 W output power when pumped by 19.9W from a diode laser. The pumping area was ellipse as a perfect matching with oscillation mode (high overlap efficiency).Fig (6) shows the relationship of pumping and output laser.



Fig(6) illustrate the relation of laser power with input power

Conclusion

From all previous results we can conclude the following points:

1. LASCD program has a good status to simulate the distribution maps of heat when laser rod end pumping by diode laser.
2. We can see the high agreement between the experimental and theoretical maps of temperature.
3. The end pump method has a good approach when we want to study the maps of heat distribution.

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